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ESEX Commentary

The Anthropocene: is there a geomorphological case?

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ESPL
Earth Surface Processes and Landforms

ABSTRACT: The ‘Anthropocene’, as used to describe the interval of recent Earth history during which humans have had an ‘overwhelming’ effect on the Earth system, is now being formally considered as a possible new geological Epoch. Such a new geological time interval (possibly equivalent to the Pleistocene Epoch) requires both theoretical justification as well as empirical evidence preserved within the geological record. Since the geological record is driven by geomorphological processes that produce terrestrial and near-shore stratigraphy, geomorphology has to be an integral part of this consideration. For this reason, the British Society for Geomorphology (BSG) has inaugurated a Fixed Term Working Group to consider this issue and advise the Society on how geomorphologists can engage with debates over the Anthropocene. This ESEX Commentary sets out the initial case for the formalisation of the Anthropocene and *a priori* considerations in the hope that it will stimulate debate amongst, and involvement by, the geomorphological community in what is a crucial issue for the discipline. The Working Group is now considering the practical aspects of such a formalization including the relative magnitude problem, the boundary problem and the spatial diachrony of ‘anthropogenic geomorphology’. Copyright © 2012 John Wiley & Sons, Ltd.

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Just over a decade ago, Paul Crutzen, a Nobel Laureate and atmospheric chemist, informally coined the term ‘Anthropocene’ to describe the interval of recent Earth history during which humans have had an ‘overwhelming’ (undefined) effect on the Earth system (Steffen *et al.*, 2007; Zalasiewicz *et al.*, 2010) and a stratigraphic argument has been outlined by Zalasiewicz *et al.* (2011). This was not an entirely new concept, with recognition having been given to human impacts in earlier centuries (Marsh, 1874) and cognate terms proposed (e.g. ‘Anthropogene’ by Nilsson, 1983). The more formal issue of whether the Anthropocene represents a new interval of geological time was aired at an international meeting of the Geological Society of London (GSL) in May 2011, receiving widespread media coverage and appearing on the front cover of *The Economist* (May 27th, 2011). The Subcommission on Quaternary Stratigraphy (SQS), a constituent body of the International Commission on Stratigraphy (ICS), has inaugurated a working group to consider the Anthropocene as a formal division of geological time. There are strong links between the SQS and the Geological Society of London (GSL), to which the British Society for Geomorphology (BSG) is affiliated. The BSG represents scientists who, *inter alia*, investigate Earth-surface processes operating in the Pleistocene and Holocene, but to date too few geomorphologists have been involved in a debate that is being promoted forcefully by geologists, ecologists, climatologists, and the global climate change community. Even if the term Anthropocene is not yet widely used in geomorphology, changes in the rates and patterns of Earth-surface processes are central to the debate (Church, 2010). Where human activity acts on the Earth’s surface, potentially this activity changes the rates at which these processes operate and may produce landforms including sedimentary deposits that are a consequence of these changed rates. Consequently, the geomorphological community cannot avoid participation in this debate and should make a significant contribution. This ESEX Commentary arises from the initiation of the BSG Fixed Term Working Group on the Anthropocene and is presented in order to stimulate informed debate within the geomorphological community.

One purpose of this Commentary is to pose the fundamental question: is such a subdivision of Earth time warranted in geomorphological terms? In answering the question, we should not, at least initially, get overly concerned with formal chronological questions relating to the status and boundaries of putative stratigraphy. Arguments concerning dominant or overwhelming human activities relate more to processes and rates than to stratigraphy, and this perspective lies at the heart of geomorphology. Rather, the answer lies in whether the rates and patterns of Earth-surface processes are so different in the time interval concerned as to make a subdivision valid and meaningful. This question is clearly methodologically challenging, and raises epistemological objections along the lines of 'wouldn't it be better to consider this in a million years time?' or 'how do you identify a new geological interval from *within* the interval'? However, given the debate has already gained momentum, the fundamental question cannot be ignored, and we should not neglect our responsibilities to science and society to embed geomorphology in the debate as an essential requirement for understanding the stratigraphic record from recent Earth history, and for how this history can be used to improve environmental management. In river restoration projects, for instance, there is the vexed issue of whether we can identify and define the 'historical range of variability' – the spatial and temporal range of river variables such as flow regime and planform that existed prior to intensive human alteration (Wohl, 2011) – and adopt this as a desirable management target. Below, we approach the fundamental question posed above through two considerations. First, have Earth-surface process domains (patterns and rates) changed fundamentally during recent Earth history with rising human population? Second, if so, will the consequences of these process regime changes be preserved in the geological record?

For the first consideration, we can use our knowledge of geomorphological processes and examine the geological record to assess whether Marine Isotope Stage (MIS) 1 – the present interglacial that has seen the rapid growth of humanity – will be significantly different from preceding interglacials in sedimentological and associated stratigraphic terms. Since the Earth is also undergoing long-term dynamics related to internal (endogenic) factors such as plate tectonics and external (exogenic) astronomical factors, it is logical to start with the most recent and astronomically comparable interglacial (MIS 5e). In cool temperate regions, MIS 5e has long been associated with high biomass production and low-energy fluvial and slope systems (Rose, 2010), conditions that produced fine grained, organic-rich river channel fills nested within antecedent cold-phase aggradational sequences. Significant overbank units are rare, and although this rarity can result from selective erosion, is fundamentally a consequence of vegetated land surfaces and stable soils, some of which are preserved as palaeosols. Within these temperate regions, slope deposits tend to be rare. By contrast, when considering the present interglacial, the widespread occurrence of later Holocene thick colluvial and overbank units in lowland European river valleys was pointed out by scientists last century (Happ *et al.*, 1940; Natermann, 1941; Shotton, 1978). Globally, these units are clearly diachronous, as shown by 'legacy' valley sediments in North America (Trimble, 1981; Walter and Merritts, 2008) and parts of the southern hemisphere (e.g. Australia – Fanning, 1994; Rustomji and Pietsch, 2007). This occurrence should come as no surprise: it has long been known, indeed since antiquity (see Plato's *Critias*), that accelerated hillslope erosion has been caused by many human activities including agriculture (Sauer, 1938), mining (Gilbert, 1877) and urbanization (Wolman and Schick, 1967), with concomitant accelerated downstream sedimentation recorded in alluvial basins and floodplains (Trimble, 1981), lakes (Dearing and Jones, 2003) and offshore (Syvitski *et al.*, 2005). Even if hillslope erosion and downstream sedimentation is most pronounced in the early phases of disturbance, and eventually decreases to lower levels (Chiverrell, 2006), these lower levels commonly still exceed background (pre-human impact) rates. Indeed, in some river systems, there is growing recognition that the human footprint is now so pervasive that we cannot hope to restore to pre-human conditions, even if we can identify and define the historical range of variability (Brierley and Fryirs, 2005), and that many floodplains can be regarded as 'genetically modified' by human activities (Lewin, 2013) that started in some cases many centuries or even millennia ago (Brown, 2008).

Nearly two decades ago, Hooke (1994) provided an early attempt to quantify continent-wide rates of earth movement by human activities, arguing that if ploughing was included, humans now displace a greater mass of rock and soil per year than all other natural geomorphic agents combined. More recently, Montgomery (2007) summarized the cultural history of soil erosion and Haff (2010) has proposed that technological 'mass-action' now exceeds that of all land-based geomorphic systems except rivers. Given the current global human population (7 billion), such quantified claims for the dominant or overriding influence of human activities are unsurprising. Even if a conservative 10 spades of soil (*c.*100 kg) were moved for every person each year, total annual human sediment flux would be *c.*700 million metric tons, which is greater than the total annual river sediment flux from Europe. Indeed, sediment 'accounting' studies have shown that humans have inadvertently increased sediment transport in rivers by approximately 300 kg per person annually (Syvitski *et al.*, 2005). Even with reservoir construction disrupting a significant proportion of the sediment transferred from land to ocean, the dominant factor in global ocean clastic sediment flux is now the direct and indirect effects of human activity (Wilkinson, 2005).

The second consideration concerns the longer term preservation potential of this increased flux. Many recent alluvial, lacustrine and offshore records demonstrate the links between human-altered earth surface processes and the resulting short- to medium-term sedimentary products, but we need to engage in thought experiments to assess whether evidence of human activities will be preserved in the *future* long-term geological record. We can postulate that beyond future glacial limits, human-induced increases in sediment flux will have driven geologically rapid aggradation in lower terrains, and continued accumulation, caused in this case by cold climate physical processes, will likely bury and 'fossilize' the products of recent human activity, from bones to buildings. Even with reservoir construction disrupting sediment flux from land to ocean, such an 'event' stratigraphy can be seen extensively within floodplains (Hoffman *et al.*, 2010; Aalto and Nitrouer, 2012), in many deltas (Evans, 2012) and on near-shore parts of continental shelves and could therefore be preserved in marine geological records. This event stratigraphy also contains a major biological discontinuity, namely a pulse in species extinction, and the appearance of alien species and a large biomass of new species, including both humans and their domesticates. Geobiological combinations also occur, such as anthropogenic soils (Wilson, 2002; Jablonski, 2004; Certini and Scalenghe, 2011; Zalasiewicz *et al.*, 2011).

From the above discussion, we present two propositions for consideration. First, there is enough geomorphological evidence to support the contention that human activities in the later part of the present interglacial have been the dominant (but not necessarily overwhelming) drivers in many, but not all, sediment-flux systems from the scale of individual hillslopes to large catchments, and as a consequence have recognizably altered the nature of terrestrial, and parts of the marine, sedimentary records. Barring unforeseen changes, the impacts of these 'forcing' activities are likely to continue into the future. Second, the human-induced alterations to terrestrial and marine sedimentary records are likely to be preserved in the long-term geological record, at least in *some* environments. Neither proposition would deny the importance of non-anthropogenic (natural) climate change and weather extremes in influencing geomorphic systems and associated sedimentary records; along with anthropogenic influences, these factors will generate difficult future environmental management issues. Likewise, although this discussion has focused largely on fluvial and colluvial systems, the role of anthropogenic factors in aeolian, carbonate and even glacial systems remain crucial avenues for research. If these two propositions are accepted, then by implication there is a *prima facie* geomorphological case for possible recognition of the existence of the Anthropocene as a time interval in Earth's history under which these conditions apply (i.e. the 'recent' past, the present and at least the near future).

However, the transition during the present Epoch (Holocene) to human-dominated geomorphic process regimes is spatially non-uniform and highly diachronous in global terms (Wainwright and Thornes, 2004). Indeed, the case can be made that human activity is certainly not dominant everywhere. In areas of active mountain building (e.g. New Zealand Alps or the Andes), tectonically- or rainfall-induced sediment movement probably outstrips human earth moving. In deserts or desert margins, natural aeolian sediment movement may exceed human earth moving and human-enhanced aeolian sedimentary signatures are likely to be indistinguishable from natural products. Indeed, the very nature of aeolian transport leads to dispersion rather than concentration of erosional products. In frozen terrains (e.g. Antarctica and under ice sheets), natural processes probably still dominate although the periglacial zone is of course highly sensitive to the removal of vegetation by human activity as well as human-induced global climate change. In all these environments, however, some elements of direct or indirect human influence can now be found (e.g. alien plants in Antarctica) and their geomorphic process regimes include some anthropogenic component, even if only secondary. Even where human activity is now dominant, the transition to a human-dominated regime is highly diachronous within the Holocene. In much of Eurasia, the transition was early but gradual, starting *c.* 4 ka, and was driven by agricultural changes. In parts of Africa, the transition may also have been early (e.g. Mali – Lespez *et al.*, 2011) but occurred later in most areas due to agricultural changes in the Iron Age and with European colonization (Schwartz *et al.*, 1990). In the so-called 'New World', although indigenous peoples had some impact on geomorphic systems (largely through the use of fire), the dominant human signal is a feature of the post-colonial era – albeit complicated in places like South America and New Zealand by lower population densities, a more fragmentary pattern of agricultural uptake, and by high, tectonically-driven background erosion rates. Recognition of diachrony does not fatally diminish the argument for recognition of an Anthropocene time interval, as all geological boundaries derived from changes in the stratigraphic record, except the Pleistocene/Holocene boundary (Walker *et al.*, 2009), have diachronies in the order of, or much greater than, 5–10 ka. However, process-based studies and complexity-theory approaches suggest that diachrony in human impacts on the landscape is likely to be the rule rather than the exception (Wainwright and Millington, 2010) and is an integral component of the Holocene and what marks it apart from the Pleistocene Epoch. Diachrony does, however, have implications both for how we demarcate the Anthropocene and potentially for its formal chronological status (e.g. Era, Period, Epoch or Stage) and therefore potentially for the duration and even status of the Holocene. If we decide that recognition of an Anthropocene time interval is theoretically justified and hence a lower boundary needs to be defined, one issue is how to prevent any formalization being constraining and arbitrary (Gale and Hoare, 2012). Even if the geomorphological community put forward some preferences for a lower boundary it would still require some diagnostic criteria by which the level of human impact on geomorphic systems and sedimentary records can be gauged and a definition of what constitutes 'overwhelming' human forcing? These issues are now being considered by the BSG Anthropocene Working Group and all contributions are welcomed (see the BSG website for an online survey where views can be presented). We need your views on the above arguments, the positive and negative aspects of formally recognizing the Anthropocene as a geological time interval and possible alternative approaches. Whether the Anthropocene does or does not become a new formal geological time interval should, at least in part, be a matter of geomorphology and thus for geomorphologists. Geomorphologists have long researched the impacts of human societies on earth surface processes and landform records, without needing the motivation of creating a new geological time interval. However, the community must wake up to the debate before they find themselves inside, outside or straddling a new geological era (small E), having had their disciplinary framework shifted under them.

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